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1 **Habitat fragmentation compromises the population dynamic of the globally near-**
2 **threatened Straight-billed Reedhaunter (*Limnoctites rectirostris*)**

3

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17

18 **Abstract**

19 Understanding the consequences of habitat fragmentation to biological populations is
20 crucial to develop sound conservation polices. The Straight-billed Reedhaunter
21 (*Limnoctites rectirostris*) is a little known and threatened Passeriform that is highly
22 dependent Erygo wetlands patches. Here, we evaluated the effects of habitat

23 fragmentation on populations of the Straight-billed Reedhaunter, during the
24 construction of a water reservoir in southern Brazil. During eight months, we monitored
25 five Eryngo wetlands patches occupied (n=3) and no occupied (n=2) by Straight-billed
26 Reedhaunter individuals, collecting data on their temporal occupancy patterns and
27 registering new fragmentation events in formally continuous habitat patches. We
28 evaluated the consequences of habitat fragmentation on the probabilities of patch
29 occupancy, colonization and extinction of populations of the Straight-billed
30 Reedhaunter using an information-theoretic approach. Out of the three patches
31 occupied by Straight-billed Reedhaunter, two were not altered by construction activities
32 and their populations were present during the entire study period. After fragmentation
33 events, local extinction in one of the wetland patches was observed, and individuals
34 were sporadically observed in two other initially unoccupied sites. The model in which
35 fragmentation affected only the extinction probability was the most plausible among the
36 set of candidate models. Fragmentation greatly increased the chance of local population
37 extinction within patches. Our results indicate that the conservation of populations of
38 the Straight-billed Reedhaunter is highly dependent on continuous and unaltered
39 wetland patches.

40 **Keywords:** inland wetlands, Eryngo, waterbird, , conservation, water reservoir,
41 perturbation, extinction, colonization

42

43 **Introduction**

44 Continental wetlands are among the most threatened ecological systems in the
45 World (Davidson 2014). In South America, habitat fragmentation of some regions has
46 reduced the surface of this ecosystem to less than 10% of its original area (Maltchik et

47 al. 2003; Guadagnin et al. 2005). One of the most interesting and little-known
48 continental aquatic systems in South America refers to those dominated by Eryngo
49 *Eryngium pandanifolium* Cham. & Schltldl. (Apiaceae), locally known as *gravatazais*.
50 These wetlands are distributed in the form of patches in the grassland landscape and are
51 periodically altered or destructed by many anthropic disturbances, such as agriculture,
52 intensive livestock, intentional fires and drainage for dam construction (Irgang 1999;
53 López-Lanús et al. 1999; Bencke et al. 2003; Volcan et al. 2014).

54 Collected for the first time in June 1833 by Charles Darwin (Steinheimer 2004),
55 the Straight-billed Reedhaunter (*Limnoctites rectirostris*) is a South American aquatic
56 passerine that strongly depends on the wetlands dominated by Eryngo (BirdLife
57 International 2016). The Straight-billed Reedhaunter has no known migratory
58 movements and its geographical distribution is limited to southern Brazil (Fontana et al.
59 2008; Bencke et al. 2010), and to neighboring countries – Uruguay (Aldabe et al. 2009)
60 and Argentina (Chebez et al 2011). Globally, this species is included within the "near-
61 threatened" category and its populations have been decreasing across its distributional
62 range (BirdLife International, 2016). At national scales, the scarce knowledge about its
63 population size and life history, along with its reduced distribution and high habitat
64 specificity has led to its inclusion in threatened species lists in Uruguay and Argentina,
65 under "near-threatened" (Aldabe et al. 2009) and "threatened" (Chebez et al. 2011)
66 categories, respectively. In Brazil, the Straight-billed Reedhaunter has been recently
67 excluded from the list of threatened species (MMA 2014)

68 *Gravatazais* present high biological, taxonomic and functional diversity,
69 including the presence of many other threatened species, such as annual fishes,
70 amphibians, birds and mammals (Fontana et al. 2003, Teixeira de Mello et al. 2011;
71 Lanés et al. 2014). However, in southern Brazil, regions with high concentration of this

72 type of wetland are also characterized by low annual precipitation, and the constructions
73 of dams have been very important for the development of cities and local communities
74 (Boschi et al. 2011). This is of particular concern as dams significantly affect the
75 population dynamic of terrestrial species (Kingsford 2000).

76 In this work, we aimed to identify the effects of habitat fragmentation on the
77 population dynamics of the Straight-billed Reedhaunter. Specifically, we determined the
78 probabilities of occupation, colonization, and extinction associated with the habitat
79 changes promoted by the construction of a water reservoir. For this purpose,
80 *gravatazais* with and without Straight-billed Reedhaunter subpopulations were
81 monitored for their presence and absence during the reservoir construction activities.
82 Given the close relationship of Straight-billed Reedhaunter to wetlands dominated by
83 *Eryngo*, we expected to find significant effects of habitat fragmentation on the
84 persistence of their subpopulations, which would reflect on the extinction and
85 colonization probabilities.

86

87 **Methods**

88 *Study area*

89 The study was conducted in the municipality of Bagé in southernmost Brazil (S
90 31° 17' 26,4' and W 54° 09' 32,7'). This region greatly represents the landscape of the
91 Pampa Biome (Rambo 1959; Overbeck et al. 2007). The study area is characterized by
92 large extensions of natural grassland, marked by the constant presence of livestock
93 (main economic activity in the region) and agricultural crops, such as corn, soy,
94 sorghum and exotic forest (IBGE 2013). Specifically, the place designated for the
95 reservoir construction covers an area of approximately 340 hectares (Figure 1). Inside

96 the construction area, an extensive riparian forest surrounds the most important
97 watercourse of the locality, called "Arvorezinha". Grasslands and drainage lines with
98 grass and low shrubs are the dominant cover inside the area, as well as patches of
99 wetlands dominated by sedge (*Eryngium pandanifolium*), reed (*Cyperus californicus*),
100 cattail (*Typha dominguensis*) and panic grass (*Panicum prionitis*).

101

102 *Patch selection and population monitoring*

103 Firstly, from satellite imagery, we identified all potential wetlands within the
104 study area. During a pilot inspection in December 2011, we excluded all sites without
105 Eryngo habitat. Five Eryngo wetlands patches were selected for research (Table 1). The
106 size of wetlands varied between 5444 m² and 34150 m². The presence of two
107 individuals of Straight-billed Reedhaunter was confirmed in three of these patches,
108 during the pilot study. Posteriorly, between September 2012 and April 2013 (except for
109 November), we conducted seven monthly visits to the five selected wetlands. In this
110 sense, including the first observation performed during the pilot inspection, eight
111 sampling visits were performed for each wetland. Nests were recorded in three patches
112 initially occupied by the Straight-billed Reedhaunter – see Gonçalves et al. (2017) for
113 more information about breeding biology.

114 During each visit, we aimed to detect the presence/absence of Straight-billed
115 Reedhaunter and whether wetlands were fragmented. We considered fragmentation to
116 be any change in the natural structure of a wetland that implied a new split of the
117 continuous patch. All samplings were made when weather conditions were favorable
118 (without rain and little wind). To facilitate the detection of Straight-billed Reedhaunte,
119 observations were always made by two researchers. "Playback" techniques were also

120 run on the edge of patches and the search time in each site varied between 1 and 2
121 hours.

122

123 *Occupancy models*

124 The presence and absence of Straight-billed Reedhaunter was modeled as a
125 function of habitat integrity (occurrence or not of one event of fragmentation or
126 destruction of the wetlands). Four parameters were evaluated: probability of occupation
127 (ψ); probability of colonization (γ); probability of extinction (ϵ) and probability of
128 detection (p) (this last was kept constant in all models as the species can be easily
129 detected). We tested the fit of four models: 1) $\psi(.)\gamma(.)\epsilon(.)p(.)$ – model in which the
130 probability of occupation, colonization, extinction and detection are constants (.); 2)
131 $\psi(.)\gamma(\text{fragmentation})\epsilon(\text{fragmentation})p(.)$ – model in which fragmentation affects
132 colonization and extinction probabilities; 3) $\psi(.)\gamma(\text{fragmentation})\epsilon(.)p(.)$ – model in
133 which fragmentation affects only the probability of colonization; and 4)
134 $\psi(.)\gamma(.)\epsilon(\text{fragmentation})p(.)$ – model in which fragmentation affects only the extinction
135 probability. We evaluated model fit using a multimodel inference approach within an
136 information-theoretic framework (Burnham & Anderson 2003, Anderson 2008). To
137 estimate model plausibility we used Akaike Information Criterion (AIC) and AIC
138 weight (w), which measures the relative likelihood of the model given the data,
139 normalized across the set of candidate models (Burnham & Anderson 2003, Anderson
140 2008). Occupancy models were fitted using the Unmarked Package (Fisk and Chandler
141 2015), in the R v3.1.3 environment (R Development Core Team 2014).

142

143

144 **Results**

145 The spatial-temporal dynamic of the Straight-billed Reedhaunter is presented in
146 Figure 2. Of these three wetlands, two were not altered by the reservoir construction and
147 the presence of individuals was constant throughout the study period. One of the
148 occupied patches (number 3, Figure 2) was partially destroyed during the breeding
149 period (Figure 3). During the next sampling periods, the species was absent in this
150 patch, and individuals were concomitantly observed in two other initially unoccupied
151 wetlands, including one already fragmented site (Fig. 2a-2d).

152 The model in which fragmentation affected only the probability extinction was
153 the most plausible (Tab. 1). Model in which fragmentation affects both the colonization
154 and extinction was also highly plausible ($\Delta AIC < 2$), although its probability was much
155 lower than the model in which the probability of extinction was a function of habitat
156 alteration (Tab. 1). Extinction probability of Straight-billed Reedhaunter tended to
157 increase drastically in fragmented wetlands (Tab. 2; Fig. 4).

158

159 **Discussion**

160 Our results highlight that the effect of habitat fragmentation on Straight-billed
161 Reedhaunter populations is significant. Fragmentation increases the extinction
162 probability of the Straight-billed Reedhaunter.

163 Habitat fragmentation results primarily in local extinction of populations with
164 consequences to their patterns of regional and global distribution (Henle et al. 2004).
165 Although species are able to occupy fragmented landscapes when their life cycles
166 include multiple fragments (Redpath 1995), the effects of fragmentation is stronger in
167 those species with specific ecological requirements (Swihart et al. 2003; DeVictor et al.

168 2008). This seems to be the case of the Straight-billed Reedhaunter. After local
169 extinction in one of the wetlands, individuals were sporadically observed in two other
170 initially unoccupied patches, including a fragmented site. Although we cannot confirm
171 that these individuals are the same as those in the previously destroyed wetlands, the
172 temporary occurrence of the Straight-billed Reedhaunter in these sites could indicate an
173 immediate attempt to extend its territory, as a result of the habitat loss and displacement
174 of competitive individuals.

175 The size and stability of the populations in natural wetlands depend strongly on a
176 range of habitat and landscape factors, as well as on body size, morphology, behavior,
177 effects of niche breadth and the effect of geographic range boundaries (Redpath, 1995;
178 Marsh and Trenham 2000; Swihart et al. 2003). Stable subpopulations were observed
179 only in unaltered wetlands, which indicate that the species' ecological plasticity is
180 apparently low. Paradoxically, the species has been known to occupy wetlands in
181 widely altered landscapes, e.g., on the edge of roads and dams (Ricci and Ricci 1984;
182 Barbarskas and Fraga 1998). We recommend taking these observations cautiously as the
183 populations may have colonized these wetlands after the alteration of the landscape,
184 which favors the colonization of *Eryngo* due to artificial water concentrations by
185 construction of roads and dams. Hence, further research is needed to elucidate the
186 effects of the area and habitat structure on the size of the subpopulations located in
187 unchanged natural patches.

188 Our results show the Straight-billed Reedhaunter populations have greater
189 stability in unaltered patches, which reduces the chances of permanence and
190 colonization in those patches subjected to fragmentation events. These results
191 demonstrate a more accurate view of this species' ecological plasticity and their
192 tolerance to habitat fragmentation, and contribute to lower the uncertainties of its degree

193 of threat at different scales. The Straight-billed Reedhaunter is globally near-threatened
194 (BirdLife International, 2016), but has been recently excluded from the list of
195 endangered species in Brazil (MMA, 2014) and Rio Grande do Sul State (Rio Grande
196 do Sul, 2014). Indeed, the number of records of this species has significantly increased
197 in recent years, especially in southernmost Brazil (Develey et al. 2008; ICMBIO, 2014;
198 Wikiaves, 2016). On the other hand, it is important to note that the knowledge about
199 many aspects of its biology and ecology is completely lacking. In this work, we discuss
200 the effect of fragmentation promoted by an activity that tends to drastically alter
201 landscapes. Additionally, these wetlands are commonly channeled for water subtraction
202 – a practice that also fragments wetlands and may have similar consequences to the
203 disturbance explored herein. Therefore, we strongly recommend understanding the
204 relationship of both the habitat structure and degree of connectivity of patches with the
205 Straight-billed Reedhaunter’s spatial distribution by identifying how environmental and
206 spatial stochastic processes on different landscape scales influence the species
207 demographic dynamics. Finally, the natural distribution of the *gravatazais* may imply
208 that the Straight-billed Reedhaunter may be distributed as a metapopulation, and we end
209 this article by encouraging further research about not only the Straight-billed
210 Reedhaunter, but also about the vast biodiversity associated with wetlands dominated
211 by *Eryngo*.

212

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215 fieldwork.

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317
318

319 **Tables**

320 **Table 1.** Model-selection table with candidate models ranked according to their AIC weights(ω) , from highest values to lowest values.

321

Model	Parameters	AIC	Δ AIC	ω
$\psi(\cdot)\gamma(\cdot)\varepsilon(\text{Fragmentation})p(\cdot)$	5	40.11	0	0.61
$\psi(\cdot)\gamma(\text{Fragmentation})\varepsilon(\text{Fragmentation})p(\cdot)$	6	42.07	1.96	0.23
$\psi(\cdot)\gamma(\cdot)\varepsilon(\cdot)p(\cdot)$	4	43.38	3.27	0.12
$\psi(\cdot)\gamma(\text{Fragmentation})\varepsilon(\cdot)p(\cdot)$	5	45.35	5.24	0.04

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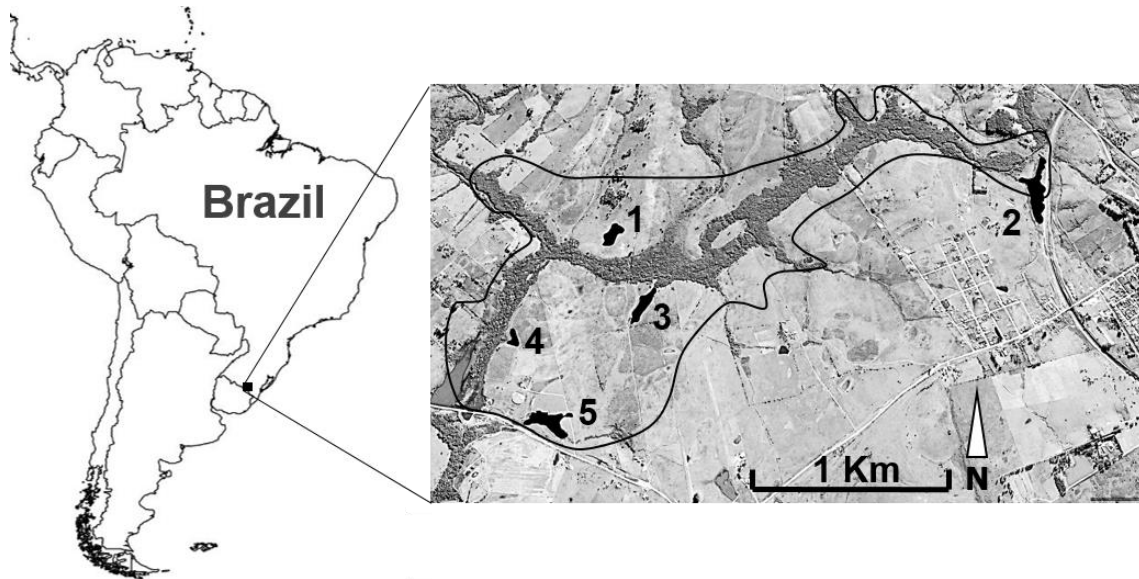
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329 **Table 2.** Probabilities estimates (\pm se) for the Straight-billed Reedhaunter for the best model after the fragmentation event. Subscript for
 330 extinction probabilities denote non-fragmented (ϵ_{nf}) and fragmented patches (ϵ_f).

Best Model	ψ	γ	ϵ_{nf}	ϵ_f	p
$\psi(\cdot)\gamma(\cdot)\epsilon(\text{Fragmentation})p(\cdot)$	0.60 (0.22)	0.12 (0.08)	0.06 (0.06)	0.67 (0.27)	1 (0)

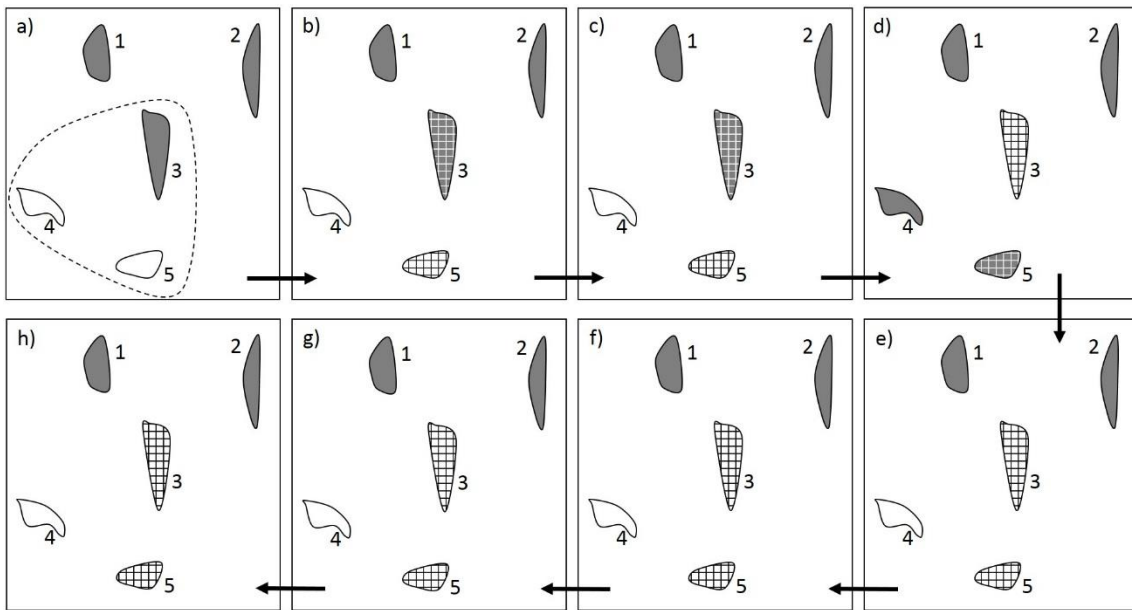
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333 **Fig. 1.** Study area located in southernmost Brazil. The continuous line demarcates the
334 approximated flooding area of the reservoir. Selected patches are numbered and
335 marked. Image dates to April 2007 taken from Google Earth Pro (accessed on 12 June
336 2016).

337



339

340 **Fig. 2.** Schematic representation of the Straight-billed Reedhaunter's occupation
 341 dynamics. A dotted line in Figure 2a marks the area affected by the construction
 342 activities. The areas with the presence and absence of species are filled in gray and
 343 white, respectively. The patches with gridlines represent the occurrence of a
 344 fragmentation event. The dates of the samples were: 2a) December 2011; 2b) September
 345 2012; 2c) October 2012; 2d) December 2012; 2e) January 2013; 2f) February 2013; 2g)
 346 March 2013; and 2h) April 2013.

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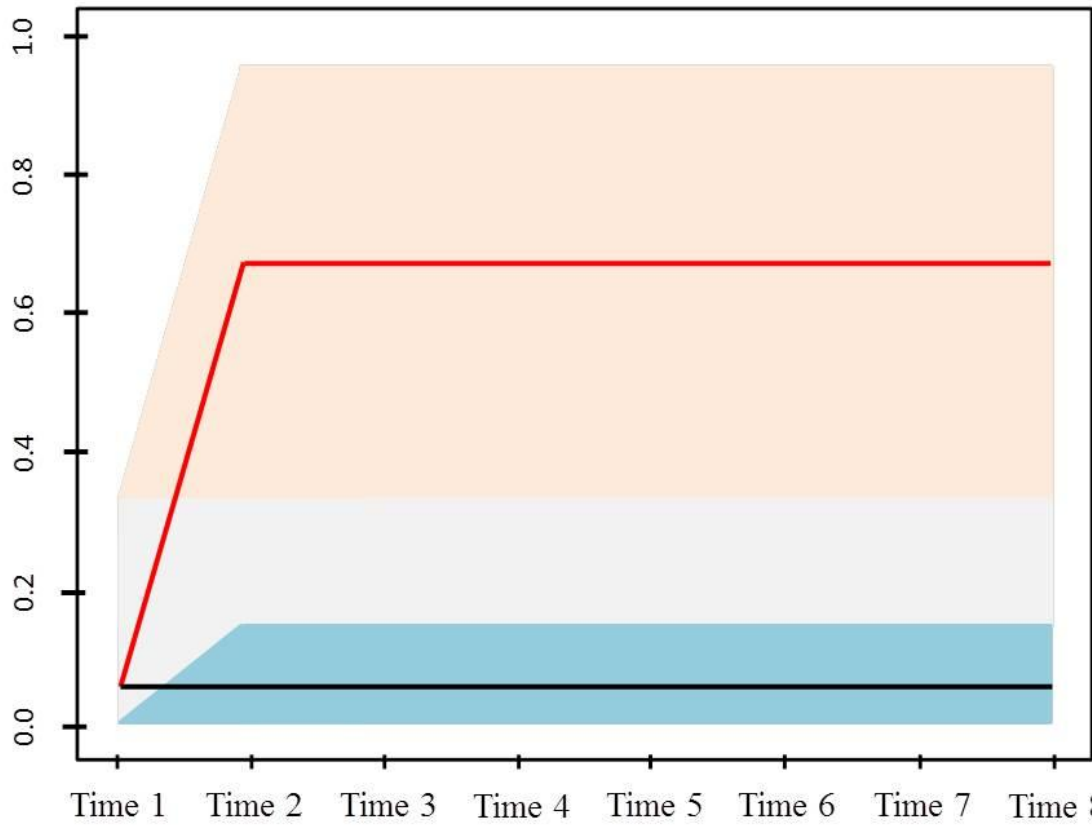
349

350 **Fig. 3a-3c.** 3a, Straight-billed Reedhaunter perched on *Eryngium pandanifolium*; 3b,
351 Nest built on the stems of "Eryngo"; 3c, wetland partially destroyed by the reservoir
352 construction activities. Photos: 3a, Christian Andretti; 3b and 3c, Priscila Pons.

353

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Fig. 4. Extinction probability (95% Confidence Interval) of Straight-billed Reedhaunter estimated for each sampling month in areas with and without fragmentation. Orange: fragmented patches; Grey: non-fragmented patches.

360

361